Climate Challenges, Ecological Modernization, and Technological Forcing: Policy Lessons from a Comparative US-EU Analysis

*Joseph Szarka**

Introduction

The international policy regime initiated by the United Nations Framework Convention on Climate Change in 1992 has yet to prove its effectiveness. During negotiation of the 1997 Kyoto Protocol greenhouse gas emission (GHG) targets of around 8 percent were discussed for regions such as the European Union and the United States of America. These goals have offered scant global climate protection, given that global CO_2 emissions alone increased by 40 percent between 1990 and 2009.[1] Indeed, the regime's effectiveness was diluted by defections, notably the United States. In the late 2000s, negotiations for a successor treaty raised hopes of a stronger regime, but the 2009 Copenhagen Accord produced little progress. Nevertheless, recognition grew of the need for stronger measures, with countries such as the United Kingdom and France inserting the aim of 75–80 percent GHG cuts by 2050 into national legislation.

Achieving ambitious long-term targets will require thorough-going climate policy renewal. Innovation in low-carbon technologies is commonly accepted as a necessary condition for emissions reduction—though it is probably insufficient on its own. Haas proposed that "the international community has a five to ten years grace period to develop the political will to commit to a massive technological push."[2] In practice, such strategies have already been implemented for several decades. The practice of "technological forcing," defined here as policy designed to accelerate technological innovation for the purposes of environmental protection, was pioneered in the United States during the 1970s and the experiment was continued in Europe with feed-in tariffs for renewable

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1. Olivier and Peters 2010, 5.
2. Haas 2008, 5.

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energy schemes and the Emissions Trading Scheme. This article will investigate what lessons can be drawn from these experiments regarding the effectiveness of technology-based policies. Have regulatory measures to accelerate technological innovation achieved their aim of improving the environmental performance of key industries? Has "technological forcing" led to major changes within highly polluting sectors or merely to incremental improvements to standard processes and products? Should policy instruments encouraging technological acceleration mainly target incumbents or new entrants? To investigate these questions, the article's first section establishes an analytical framework by reviewing the contribution of ecological modernization theory to environmental and climate policy debate. Its second section uses three case studies to explore the capacity of "technological forcing" to translate ecological modernization theory into effective policy and practice.

Based on this analysis, the argument is made that the pace of incremental technological improvements has proved insufficient to address climate challenges, therefore more fundamental changes will be required within key industries. Ecological modernization theory provides insights into how such changes can be achieved, through policy frames that stress not just technological innovation, but also the development of supportive political and institutional frameworks. Further, it identifies a significant blockage, namely large corporations who have a vested interest in preventing fundamental changes and are skilled in hijacking ecological modernization processes. A key finding is that the acceleration of technological innovation cannot meet the objectives of climate protection *unless* the resistance of powerful incumbents is overcome. The three case studies examine key junctures at which such resistance occurred, and enable identification of countervailing strategies in the concluding section.

Ecological Modernization Theory: Boundary Conditions and Internal Tensions

A frequent perception or belief found in policy debates is that the pursuit of vigorous environmental and climate protection impedes economic growth. In contrast, ecological modernization (EM) theory holds that economic growth is not only compatible with environmental protection, but that the two are mutually reinforcing. EM theory is associated with the "Berlin school" of environmental research from the 1980s, with Joseph Huber and Martin Jänicke among the seminal figures. Key propositions are that ambitious environmental targets lead to technological innovation and greater economic competitiveness. Pathways to the reduction of economic costs include "dematerialization," with lower rates of usage of physical resources, and the "decoupling" of energy and material inputs from growth, leading to greater resource productivity and reduced energy intensity.[3] The drive for efficiency gains in industrial production is accompanied by

3. Weizsäcker, Lovins, and Lovins 1997.

environmental benefits due to declining levels of waste and pollution, and reduced pressure on natural capital. This provides EM with the motto of "pollution prevention pays," namely that an upstream strategy is beneficial in both ecological and financial terms. Thus EM is linked to the development of "cleaner" technologies and new markets for "green" goods and services. Technological innovation allows the creation of "lead markets"—and therefore market leadership for pioneering firms and countries—bringing new jobs and economic growth.[4] A condition for success is proactive policy-making, characterized by Weale as "a positive role for public authority in raising the standards of environmental regulation, as a means of providing a spur to industrial innovation."[5]

EM has aroused debate over its status as theory, the nature of its knowledge claims and the demonstration of its propositions. In terms of status, views have varied as to whether EM constitutes a full-blown sociological theory, capable of providing explanatory insights into late modernity, or a policy paradigm, constructed on prescriptive tenets. Thus Barry conceptualized the functioning of EM analysis as "primarily a boundary setting organizational phenomenon,"[6] which organizes principles, actors and processes either into or out of the analytical frame. Boundary conditions arise at the cognitive and empirical levels. At the cognitive level, one category of commentaries pursues the two-fold epistemology of EM—as both social theory and policy paradigm—in order to develop new analytical perspectives. Another category considers EM as simply a policy paradigm, or a form of enlightened empiricism. In the first category, Spaargaren and Mol proposed EM as both "a political program to direct an environmental policy" *and* "a theoretical concept for analyzing the necessary development of central institutions in modern society to solve the fundamental problem of the ecological crisis."[7] Hajer contrasted a techno-corporatist form of EM, based on expert knowledge and public administrative decision-making, with a reflexive form allowing for "deliberate and negotiated social choice."[8] Christoff proposed a distinction between a "weak" variety of EM, understood as technocratic instrumentality directed to technical innovation, and a "strong" variety providing effective ecological protection through a high level of deliberative democracy.[9] Yet Langhelle objected that such claims unhelpfully shifted the boundaries of EM since "the features that Christoff relates to the notion of 'strong' ecological modernization, however, are so removed from the conventional uses of the concept that it is hardly recognizable."[10] From this perspective, EM is viewed as mere policy paradigm, so constituting an illustration of the second category. Other

4. Jänicke and Jacob 2004.
5. Weale 1992, 78.
6. Barry 2005, 305.
7. Spaargaren and Mol 1992, 334.
8. Hajer 1995, 280–3.
9. Christoff 1996.
10. Langhelle 2000, 314.

scholars too have cast doubts on whether EM constitutes social theory. Buttel questioned whether EM qualified as a "well-developed and highly-codified social theory,"[11] whilst Toke pointed to its failure to deal with equity issues.[12] Blühdorn sets out to break "the connection between the reformist practice of ecological modernization and the theory of social change that has grown around it."[13]

These caveats on EM's status as social theory suggest that its more robust contribution is as policy paradigm. As such, EM has a relatively well-developed career, with policy makers evolving a mix of both state-centered and market-oriented approaches. Despite appearances, "command and control" has not been abandoned, but EM has moved beyond the "end of pipe" methodology adopted in the 1970s. Measures include public investment in research and development, promotion of environmentally friendly behavior through education programs, and taxes to orientate production and consumption towards greener goods and services. EM has favored "new environmental policy instruments"—such as voluntary agreements, eco-audit and management systems, and latterly emissions trading—considered to have greater market conformity and effectiveness at lower cost.[14]

Yet pruning EM back to its original remit as policy paradigm has its snags. A central but problematic proposition is that environmental problems can be solved by technological innovation and further industrialization. This has resulted in a "techno-optimist" variant of EM, identifiable by its penchant for "no-regrets" and "win-win" rhetoric,[15] and a stress on being "green and competitive."[16] "Techno-optimism" has been criticized for promoting conventional economic growth and perpetuating "business-as-usual" practices.[17] Johnson argued that EM was being adapted to fit with neoliberal globalization driven by free trade and multinational corporations, but this adaptation merely legitimated environmental degradation and blunted EM's radical edge.[18]

To correct the excesses of techno-optimism, Jänicke urged that "governance for sustainable development cannot succeed if it does not include structural solutions."[19] The question of structural change is, indeed, a major theme in the EM literature. Somewhat unhelpfully, multiple meanings have been ascribed to structural change. Simonis conceived it "in the form of de-linking economic growth from environmentally relevant inputs."[20] But this does little more than reiterate the EM tenet that ecoefficiency involves greater resource pro-

11. Buttel 2000, 57.
12. Toke 2001.
13. Blühdorn 2000, 209.
14. Jordan, Wurzel, and Zito 2003.
15. Elkington 1994.
16. Porter and Linde 1995a.
17. Andersen and Massa 2000.
18. Johnson 2004.
19. Jänicke 2007, 26.
20. Simonis 1989, 349.

ductivity. Murphy and Gouldson conceptualized structural change as macroeconomic evolution, with a compositional shift from resource-intensive manufacturing industry to knowledge-based service sectors.[21] In contrast, Jänicke and Jörgens proposed a middle-range perspective which "consists of prompting environmentally relevant sectors such as transport or energy to adopt environmentally oriented sectoral strategies themselves," with a view to achieving "long-term sectoral structural change."[22] On this view, industrial sectors restructure internally in terms of their processes, products and associated infrastructures. This middle-range (or "meso") perspective will be adopted in this article because it provides a commonly accepted methodology for the identification of key actors and their interactions, facilitates assessments of change processes, yet retains sufficient scale to respond to the goal of climate protection.

But how are structural solutions to be achieved? Researchers in the 1990s delved relatively little into the mechanisms and motivations whereby EM ambitions for structural change were promoted or thwarted. Environmental crises, scientific understanding, technological innovation and political will no doubt constitute driving forces, but the question of their adequacy to EM ambitions remains open, given the characteristics of the globalizing market economy and the strategies of major players. More recent contributions have helped fill the gaps in our understanding. Jänicke noted three major obstacles: being content with plucking the low-hanging fruits of ecoefficiency, the neutralization of incremental environmental improvements by economic growth, and organized opposition given that "ecological modernization typically meets the resistance of 'modernization losers' that are often powerful enough to limit the scope and effects of environmental policy."[23] The losers are identified as vested interests that dominate long-standing industrial sectors. Such resistance reveals a boundary condition for the practice of EM, whilst finding ways to reduce resistance becomes an important policy consideration.

The obstacles noted above raise the issue of the institutional conditions under which EM can develop. In the past, these appeared relatively restrictive involving an active central state, a tradition of environmental regulation and a tendency to corporatism. The two cases most cited were Germany and the Netherlands.[24] However, more recently Barry and Paterson with regard to the UK and Zhang, Mol and Sonnenfeld with regard to China have analyzed emergent trends towards EM.[25] Significantly, the European Union has espoused EM tenets. Weale pointed out that the Third Environmental Action Program of 1983 was already marked by EM thinking.[26] Gouldson and Murphy identified EM development along four dimensions—positive linkage between environmental

21. Murphy and Gouldson 2000.
22. Jänicke and Jörgens 2007, 185–7.
23. Jänicke 2007, 26–7.
24. Weale 1992, 79–88; and Dryzek 1997, 137–141.
25. Barry and Paterson 2004; and Zhang, Mol, and Sonnenfeld 2007.
26. Weale 1993, 207.

protection and economic growth, integration of environmental concerns into other policy areas, exploration of innovative policies, and diffusion of "clean" technologies.[27] Baker focused on the ecomodernist turn in EU discourse.[28] The EU's Sixth Environmental Action Program set out "to achieve a de-coupling of resource use from economic growth through significantly improved resource efficiency, dematerialization of the economy, and waste prevention."[29] Further, the European Commission's intention of "boosting growth and jobs by meeting our climate change commitments" positioned EU climate measures within an EM trajectory.[30] Declaratory commitments to ecological modernization and to climate protection converged in the "climate-energy package."[31] The EU committed to reduce GHG emissions by 20 percent, source 20 percent of energy from renewables, and achieve a 20 percent improvement in energy efficiency by 2020. The package illustrated the EU's aspiration to climate leadership in international negotiations.[32] On the other hand, the incorporation of EM principles into US policy making has proved contentious. Dryzek et al. asserted that "ecological modernization is not part of US policy discourse."[33] However, based on case studies of American corporations, Porter and Linde had already pioneered the ecoefficiency argument in the 1990s.[34] Schlosberg and Rinfret have recently argued that "ecological modernization, American style" was on the upswing.[35] But because climate protection in the United States remained under-developed during the George W. Bush presidency,[36] there was no clear-cut translation of EM into US climate policy.

Building on the preceding discussion, this article examines "technological forcing"—understood as policy processes that seek to accelerate technological innovation for the purposes of environmental protection—through the lens of EM theory. At the conceptual level, EM provides a framework for policy analysis which helps explain the conditions and causes behind policy outputs, provides criteria for assessment of policy outcomes, and may suggest improvements to policy design. Further, EM makes a number of claims—some fairly bold—that can be tested by reference to the practices of technological forcing. At the empirical level, the aim then is to review the capacity of technological forcing to translate ecological modernization theory into effective policy. To what extent do the outcomes of particular cases of technological forcing conform to the generic predictions made by the theory? To explore this issue, four key EM propositions will be tested:

27. Gouldson and Murphy 1996, 17–18.
28. Baker 2007, 304.
29. CEC 2001, 5.
30. CEC 2008a, 1.
31. CEC, 2008b.
32. Wurzel and Connelly 2011.
33. Dryzek et al. 2003, 174.
34. Porter and Linde 1995a, 1995b.
35. Schlosberg and Rinfret 2008, 68.
36. Harrison 2007.

1. environmental and economic measures are mutually supportive;
2. pollution prevention pays;
3. ecomodernist practices lead to structural change; and
4. modernization losers offer resistance to change.

Propositions (1) and (2) reprise classic EM position statements on the relationship between ecological and economic progress. With proposition (3), the key ecomodernist practice under investigation is the capacity to accelerate technological innovation: this is the source that provides many derived gains such as enhanced resource productivity, reduced pollution, etc. The broader outcome of these processes is posited to be structural change. To identify occurrences of the latter, the middle-range definition proposed by Jänicke and Jörgens of "long-term sectoral structural change" will be used,[37] as discussed above. In order to ascertain whether ecomodernist practices have caused sectoral structural change, the following indicators will be used: widespread diffusion of new technologies, revised standard operating procedures, arrival of major new entrants, extensive modification in ownership of productive assets and/or redistribution of market shares. Proposition (4) reflects the need to investigate incumbent behavior and its capacity to derail, dilute or defer ecomodernist gains: this leads on to consideration of the political and institutional strategies to overcome resistance. The relationship between (3) and (4) is elucidated by the observation that "radical innovation often creates great difficulties for established firms . . . and can be the basis for the successful entry of new firms or even the redefinition of an industry."[38] In other words, "industry redefinition"—understood as the extreme form of sectoral structural change—occurs when incumbents either embrace radical innovations or are unable to oppose their uptake by third parties. These EM tenets provide the conceptual framework for investigation of three cases of technological forcing and identification of key policy lessons.

Technological Forcing in Ecological Modernization Perspective: Three Case Studies

The case studies have been selected to cover industrial sectors that are crucial for climate protection, on the assumption that American and European experiments to reduce atmospheric emissions have significant consequences for the rest of the planet. In Europe, climate change mitigation is considered "impossible without transport" by the European Environment Agency.[39] In the United States, GHG emissions from transportation account for more than a quarter of national emissions, and are increasing faster than in any other sector.[40] Further,

37. Jänicke and Jörgens 2007, 187.
38. Henderson and Clark 1990, 9.
39. European Environment Agency 2010.
40. EPA 2006, 1.

the International Energy Agency has reported that "if left unchecked globally, electricity alone could greatly reduce the chances of stabilizing the world's climate at a sustainable level."[41] Consequently, the following cases will be investigated: (1) technology forcing in the United States to reduce atmospheric pollution from road vehicles; (2) the EU Emissions Trading Scheme to cut CO_2 from industrial installations, especially power stations; and (3) support schemes in European countries—particularly feed-in tariffs—to promote electricity generation from renewable energy. Thus each case features a groundbreaking policy experiment, aimed at encouraging technological acceleration and undertaken in the major industrial sectors where climate policy needs to operate. But whether the outcomes of each conform to EM predictions will now be investigated.

Technology Forcing in the United States

The practice of technology forcing (TF) was defined by Nentjes, Vries and Wiersma as the regulatory imposition of "standards that require a higher rate of emission reduction than currently available 'off-the-shelf' technologies can offer."[42] Pioneered in the United States during the 1970s in relation to road vehicle emissions, TF's ecomodernist thrust was recognized early on. In a seminal article, Ashford, Ayers and Stone stressed that "such a strategy builds on the thesis that health, safety and environmental goals can be co-optimized with economic growth through technological innovation."[43] Gonzalez described this policy regime as "the ecological modernization of the gasoline-burning internal combustion engine."[44] Major implementations of TF related to car tailpipe emissions, lead removal from petrol, fuel economy standards and low emission vehicles.

The 1970 US Clean Air Act required that emissions from new cars be reduced by 90 percent against the 1970 baseline, setting target dates of 1975 for carbon monoxide and hydrocarbons and 1976 for nitrogen oxide, with large fines for non-compliance. These measures met with stiff resistance from the car manufacturers.[45] They successfully lobbied for postponement of the 1975–6 deadlines to 1977–8, but catalytic converters became standard in the late 1970s and three-way converters from 1981.[46] The Environmental Protection Agency initiated the leaded petrol phase-out in 1972 to take effect from 1974, but industry resistance and the oil crisis caused postponements until the 1980s, with a ban achieved only in 1994.[47] These measures were distinctive in involving a reg-

41. International Energy Agency 2009, 26.
42. Nentjes, Vries, and Wiersma 2007, 904.
43. Ashford, Ayers, and Stone 1985, 420.
44. Gonzalez 2001, 327.
45. Lundqvist 1980, 132–142.
46. Gerard and Lave 2005, 2007.
47. McGarity 1994, 947–952.

ulator with a clear and strong mandate, known but immature technologies, and limited information asymmetry between regulator and industrialists. The conversion costs to catalytic convertors and unleaded petrol proved modest from the outset, turning to negligible as mass production moved the technologies rapidly down the price curve. International diffusion effects were also significant. Despite these favorable conditions, US regulation was imposed in an adversarial setting.

Cuts in vehicle emissions improved air quality standards. Without them, the draconian experiments seen in the 2000s (city congestion charges, alternating days of car usage, etc.) would have been needed sooner. TF postponed the need for stricter measures and extended the life-span of the internal combustion engine (ICE), which constituted a victory for the corporations dependent on it. Pollution prevention did pay, for industrialists who extended the longevity of standard products and for society who enjoyed the public good of an improvement in air quality. But the environmental benefits proved temporary, being cancelled out by an increase in traffic volume. Thus although a short-term "win-win" can be identified, from a long-term perspective the outcome proved inadequate. A key policy lesson is that EM in practice proves considerably more complex than its core tenets predict. The regulatory pressures created by TF threatened to turn auto manufacturers into modernization losers and hence aroused their resistance. But the manufacturers turned the tables. They redistributed implementation costs to users, with far less pain to themselves than their early cost-benefit analyses and public relations (PR) campaigns claimed. In consequence, the hegemony of road transport and the maintenance of the incumbents' dominant position were achieved at low cost to them.[48] A crucial empirical limitation on EM was that assuring a measure of compatibility between economic and environmental objectives served to preserve "business as usual."

The history of US fuel economy standards teaches similar lessons. Improved fuel economy should be a classic "win-win" with lower emissions, lower user costs, and less dependence on oil imports. Yet US car manufacturers persistently opposed fuel economy regulations. To cut petroleum imports, Congress introduced Corporate Average Fuel Economy (CAFE) standards during the 1975 oil crisis and maintained them thereafter. They proved successful during the period of high oil prices. Greene explained the doubling of US passenger car fuel economy between 1975 and 1984 by the fact that "the standards substantially achieved their objective of restraining US oil consumption . . . because they were set at levels that could be achieved by cost-effective or nearly cost-effective technological innovations."[49] However, oil prices slumped in the mid-1980s, feeding through to low prices at the pump since the United States has low fuel taxes (unlike European countries). With US consumers having little economic incentive to purchase fuel-efficient cars, demand was diverted to the "gas-guzzling" vehicles that provided auto manufacturers with high profits. The car

48. Paterson 2007.
49. Greene 1998: 595.

lobby fought "bitter political battles" against the CAFE standards,[50] mounting large-scale PR campaigns that wrongly claimed that consumers faced excessive costs and US jobs would be lost.[51] Gerard and Lave noted that "in 1986 and 1987 Congress simply relaxed the standards so that Ford and GM would not be saddled with millions in fines."[52] Further, the increasingly dominant and profitable market segments of light trucks and sports utility vehicles were never included in CAFE standards because of industry opposition, despite poor fuel economy. Yet efficiency improvements, like the conversion to catalytic converters and unleaded fuel, needed only incremental improvements to known technologies. Although none of these measures threatened the dominance of incumbents, they were fiercely opposed. So was there any scope for TF measures with the potential for sectoral structural change?

Due to acute air pollution, California is a pioneer in demanding improved environmental performance from road vehicles, but its efforts met opposition from industrialists and sometimes the federal government. In 1990, the California Air Resource Board mandated sales of low emission vehicles, including the requirement that 2 percent of all new cars sold in California be zero emission by 1998, rising to 5 percent in 2001–2 and 10 percent in 2003. This represented a potential market of 300,000 to 400,000 units, were the measures rolled out across the United States.[53] Whilst technologies were not specified, only electric vehicles (EVs) were deemed capable of meeting the deadlines. Here was an instance of TF with the potential to induce sectoral structural change, since the ICE would lose meaningful market share. EVs provided an instance of what Bower and Christensen called "disruptive technologies,"[54] which offer opportunities to new entrants from outside an existent sector to destabilize incumbents and wrest market dominance from them.[55] The EV did away with the ICE, and with it went the incumbents' hard-won technological supremacy and attendant barriers to market entry. In came a vehicle with greater energy efficiency, fewer moving parts, less need for maintenance and replacement kit, whilst requiring unfamiliar flexible production methods.[56] Additionally, it changed the energy sourcing equation, incurring the ire of the oil majors by favoring the electricity utilities. These factors gave the EV clear potential for sectoral structural change, or even "industry redefinition." The "big three" producers—General Motors, Ford and Chrysler—refused any such prospect and strongly resisted the California mandate.[57] In practice, the take-off of EVs failed to occur in the 1990s (but is now feasible for the 2010s). Whether the incumbents conspired to "kill" the EV

50. Shaffer 1992, 198.
51. Doyle 2000, 239–270.
52. Gerard and Lave 2003, 3.
53. Cowan and Hultén 1996.
54. Bower and Christensen 1995.
55. New entrants can also come from *inside* an existing sector, in the case of foreign competition. In contrast, the manufacture and distribution of EVs can be undertaken by firms with little or no background in ICE production.
56. Shnayerson 1996.
57. Schot, Hoogma, and Elzen 1994.

remains controversial,[58] but deep acrimony is illustrated by the numerous suits filed in US courts by auto manufacturers against the California mandate, and against the manufacturers by environmentalists for undermining it.[59]

Despite its shortcomings, the legacy of US technology forcing is significant. TF demonstrated that regulation can encourage technological innovation that reconciles economic and environmental objectives, but does so in a complex fashion. Public policies forced US car makers to improve their environmental performance, but also served the sector's interests by preserving the dominance of the ICE. Even so, obsession with short-term returns led to persistent recalcitrance by incumbents. Having dismissed the need for air quality improvements in the 1970s, in the 1990s US auto manufacturers joined the Global Climate Coalition, which contested the existence of global warming.[60] The consequence of foot-dragging, costly PR and legal campaigns and technological conservatism was vulnerability to foreign competitors, especially from Japan. The financial crisis of 2007–8 exposed the failures of the US auto industry: on the verge of bankruptcy, it pleaded in Washington for federal bail-outs. With restructuring of the car sector probable for the 2010s, technological forcing to produce low-carbon vehicles and create jobs in "greener" firms has acquired renewed relevance.

The EU Emissions Trading Scheme

Emissions trading is intended to make "pollution prevention pay" by putting a price on carbon and creating market pressures for emission cuts. Described by Delbeke as "the cornerstone of the EU's implementation of the Kyoto Protocol,"[61] the Emissions Trading Scheme (ETS) may offer an exemplar for future regional or global schemes. Skjærseth and Wettestad observed that "the EU has economic incentives to develop the EU ETS to reduce compliance costs with the Kyoto target."[62] In seeking to demonstrate that major GHG cuts are feasible and affordable, the ETS constitutes an example of EM in practice, with the potential to accelerate innovation in low-carbon technologies. As such, it has elements of continuity with the US practice of TF. Once again, higher rates of emission reduction are sought than conventional technologies usually provide. But whereas TF in the United States relied on "sticks" (namely, the imposition of fines for non-compliance), the EU ETS offers "carrots" (taking the form of profits from permit sales for firms capable of bettering their targets). This provides an illustration of the trend in EM away from "pure" regulation and towards market-oriented measures. The challenge for both TF and ETS is the same,

58. A documentary on this topic, entitled *Who Killed the Electric Car?*, was directed by Chris Paine and distributed by Sony Pictures in 2006.
59. Doyle 2000, 305–323; and Calef and Goble 2007.
60. Kolk and Levy 2003.
61. Delbeke 2006, 1.
62. Skjærseth and Wettestad 2008, 183.

however, namely to design a policy that is sufficiently demanding to promote a wave of innovations over the medium to long term, yet realistic enough to overcome short-term resistance.

The design of ETS is based on the cap and trade principle: the lower the cap, the greater the environmental benefits. This is because scarcity in the permit market forces companies to make process and product innovations. Set up under Directive 2003/87/CE, the ETS targeted the electricity, energy, steel, cement, chalk, glass, ceramics, paper and cardboard sectors, covering some 12,000 factories producing 45 percent of industrial CO_2, equivalent to 35 percent of total GHG emissions in the EU.[63] The scheme has evolved through three phases: a trial phase between 2005 and 2007, an operational phase between 2008 and 2012 (to coincide with the Kyoto Protocol's first commitment period), and a revised phase for 2013–2020.

In phase one, permits were allocated (a) free; (b) in proportion to historical emissions; and (c) by national authorities. These features reflected the preferences of member states and interest groups.[64] Indeed, the European Commission's view was that ETS would be accepted only if it met target group preferences.[65] The danger of excessive permit allocations to protect national industries was recognized early.[66] However, hostile lobbying by industrialists claiming a heavy financial burden in the context of decentralized (and largely uncoordinated) distribution led to systematic over-allocation that, once discovered, precipitated a collapse in permit prices in April 2006.

For the carbon market to work correctly, the phase two cap needed to be tight. In late 2006, the European Commission rejected several National Allocation Plans (NAPs) and told domestic authorities to reduce allocations, signaling its intention to tackle market distortions arising from decentralized distribution. Poland and six member states filed legal action against the Commission in March 2008. This revealed the willingness of some member states to defend the economic interests of their heavily polluting industries. Overall, phase two NAPs contained only an average 5.9 percent cut in emissions against the 2005 baseline.[67] Further, some incumbents made easy profits from emissions trading with the electricity sector being a case in point, given its ability to pass CO_2 costs through to captive customers.[68] It was estimated that the German power sector could gain windfall profits of between €14 and €34 billion during phase two by incorporating the market value of allowances into wholesale electricity prices.[69] Utilities in other EU member states would also make windfall profits, but at lower levels. The cause is not improper activity, but the policy design fault that

63. Andersen 2005, 143.
64. Markussen and Svendsen 2005; and Skjærseth and Wettestad 2009.
65. Vis 2006, 190.
66. Delalande and Martinez 2004, 108–9.
67. Ellerman and Joskow 2008, 33.
68. Sijm, Neuhoff and Chen 2006.
69. Point Carbon Advisory Services 2008.

permits were distributed free to polluters. These outcomes prompted strong reactions, ranging from outright condemnation of emissions trading from NGOs such as Friends of the Earth to calls for radical redesign of ETS.[70]

Phase three promised greater ambition. The 2020 target is a 21 percent emissions cut within the ETS perimeter, and 100 percent auctioning of permits was proposed. This prompted another round of hostile lobbying by industrialists, with some national governments arguing against auctioning. European energy intensive firms exposed to international competition feared loss of business because overseas rivals did not integrate carbon costs. Industry resistance led to the dilution of auctioning. Skodvin, Gullberg and Aakre observed that "exemptions from the basic principle of full auctioning of GHG emissions allowances can all be traced to target-group interest representation by single veto players or blocking minorities in the European Council and the Council of Ministers."[71] Firms exposed to international competition could make credible threats regarding the shutdown of production in the EU, whereas the protected electricity sector could not. In consequence, Directive 2009/29/EC established a multi-tier ETS, whereby electricity utilities were obliged to purchase 100 percent of their allowances at auction, whilst sectors characterized by a high risk of "carbon leakage" could receive their allowances free. Even so, nine Eastern European member states (and Cyprus) were allowed to apply for reduced levels of auctioning for their electricity generators (but with at least 30 percent auctioning in 2013), while less affluent EU states—14 in total—will benefit from extra allowances for auction "for the purpose of solidarity and growth."[72] Hence ETS has gone from being a unified system to a multi-tier approach. Auctioning will generate a new revenue stream for national governments, of which at least half is intended to go to climate protection and promotion of low-carbon technologies.

In summary, although carbon pricing raised fears of heavy economic burdens, costs have been light due to a policy design that bowed to the preferences of vested interests. In the long term, the "win-win" relationship between the environment and the economy that EM posits remains a possibility, but under particular conditions. One is that the rest of the world follows suit, in particular the United States. The other is that sectoral structural change is actively promoted, such that low-carbon industries come to displace the largest emitters, particularly in electricity generation. Neither of those conditions can be taken for granted. The momentum for introducing cap and trade legislation in the United States petered out over 2009–10. Further, no evidence has so far emerged to demonstrate that ETS is leading to sectoral structural change. Indeed, the scheme's capacity to encourage even incremental technological innovations has yet to be proven. The major gap in EU ETS is the lack of incentives targeted at

70. Douthwaite 2006.
71. Skodvin, Gullberg, and Aakre 2010, 854.
72. CEC 2009.

new entrants who bring forward low-carbon technologies. Perversely, its design features have buttressed incumbent polluters, especially in electricity generation from coal. Modernization's losers have achieved success in resisting technological forcing.

Electricity from Renewables in the EU

The drivers for the uptake of renewable energy have been improved energy security through use of indigenous sources, and combating climate change by a transition away from fossil fuels. The Renewables Directive 2001/77/EC established an EU-wide target of 22.1 percent of electricity to come from renewable energy sources (RES-E) by 2010. Expansion has occurred principally in wind power, whilst generation from biomass, landfill gas and photovoltaic cells has also benefited. The wind power leaders are Denmark, Germany and Spain, having respectively some 15 percent, 6 percent and 10 percent of electricity generated by wind. Around 20 percent of electricity is expected to be wind-generated in several EU countries by 2020, with other RES-E also making contributions. This level of penetration of renewables involves displacement of coal and gas-fired generation. These developments point to core EM ingredients: emission reductions, creation of "green" technologies and markets, and indeed sectoral structural change. The latter can be assessed by changes in market share of energy sources and in ownership of generating assets.

The RES-E policy framework has accelerated the development of renewable energy conversion technologies. The most widely used instrument in the EU has been "feed-in" tariffs (FITs),[73] which offer a premium price for generation from renewables (to compensate for low competitiveness compared to steam-based generation). In Germany, the usage of FITs has been refined in iterative fashion since 1991, with an important diffusion effect to other countries.[74] German usage incorporated the "degression" principle, meaning phased reduction of subsidies over time. This is a form of technological forcing because phased degression obliged industrialists to systematically improve the technical and economic performance of their wind turbines to compensate for subsidy reduction.[75] Ever larger and more efficient wind turbines were developed, principally in Denmark, Germany and Spain, with 1–2MW machines constituting the norm onshore and 5MW machines available for offshore. Greater efficiency led to greater competitiveness, and less need for subsidy. In the pioneer wind power countries, marginally higher electricity costs were offset by technological leadership, employment creation and export opportunities in a new industry. Thus the wind turbine industry provides an example of EM in action.[76]

But wind power also saw resistance, including from modernization losers.

73. CEC 2005.
74. Busch and Jörgens 2005.
75. Jacobsson and Bergek 2004.
76. Toke and Strachan 2006.

The legality of the 1991 feed-in law was contested by major German utilities PreussenElektra (now E.ON) and RWE on the grounds of incompatibility with EU liberalization of electricity markets. The European Court of Justice ruled that the German law conformed to EC legislation and confirmed the legitimacy of FITs. The incumbents did not abandon their opposition to feed-in tariffs, however. They reverted to lobbying at national and EU levels for their preferred policy instrument, namely tradable certificates.[77] Their strategy revealed that incumbents were opposed not so much to wind power per se as to the policy instruments which threatened their economic interests.[78] This is demonstrated in the UK case where the German utilities E.ON and RWE are major players in the wind sector and in the take-off of the Renewables Obligation, which is a variety of tradable certificate system. Crucially, FITs give guarantees to generators in relation to prices, sales and (sometimes) grid access and so incur low investment risk, whereas tradable certificate schemes present high investment risks in failing to offer guarantees in one or all of these areas.[79] Incumbents have the expertise to manage risk—unlike small suppliers to whom it is a barrier to entry—but demand a high risk premium in return, increasing the costs of tradable certificate schemes for consumers. This has had consequences for ownership in the UK, where the utilities own 81 percent of wind power capacity and maintain dominance,[80] and where there is no major domestic manufacturer of wind turbines. On the other hand, use of FITs has demonstrated that modest but predictable returns can attract new entrants, with small investors and cooperatives having a significant presence in the wind sectors of Denmark and Germany. Hence the positive consequences of FITs are not only innovations in low-carbon technologies and emergence of market leading firms, but also reductions in pro rata subsidy costs, promotion of new ownership forms and a push to sectoral structural change.

The wind power case-study once again illustrates the complexities of the practice of EM. The burden of financing subsidies is offset (at least in the pioneer countries) by the development of a new industry, job creation and export earnings, thereby creating a critical mass of producers and users favorable to industry redefinition. Yet this "win-win" relationship between the environment and the economy still creates modernization losers who resist sectoral structural change. In addition, the modernization process has been complicated by societal contestation of wind power, with varying consequences across countries.[81] Because of different choices of policy instrument and ensuing outcomes, an important degree of sectoral change has occurred in the electricity supply industries of Denmark and Germany—where RES-E has taken substantial market share due to feed-in tariffs—but not in the UK.

77. Jacobsson et al. 2009.
78. Szarka 2010.
79. Mitchell, Bauknecht, and Connor 2006.
80. Stenzel and Frenzel 2008, 2646.
81. Warren et al 2005; Szarka 2007, 161–181; and Barry et al 2008.

Conclusion

Analysis of three cases of technological forcing, understood as public policies to accelerate technological innovation for the purposes of environmental protection, has shown the relevance of this approach for climate protection. Whilst the economic means differed across cases (fines, profits from emission trades, subsidies), the same goal of enhanced technological and ecological performance was pursued in each. Further, the practices of technological forcing have allowed examination of whether key propositions of EM theory meet with empirical support, namely whether or not (1) environmental and economic measures are mutually supportive; (2) pollution prevention pays; (3) ecomodernist practices lead to sectoral structural change; and (4) modernization losers offer resistance to change. Through testing these propositions, policy lessons were sought out in response to the following research questions: Have regulatory measures to accelerate technological innovation achieved their aim of improving the environmental performance of key industries? Has technological forcing led to structural change within highly polluting industries, or merely to incremental improvements to standard processes and products? Should policy instruments be directed mainly at incumbents or new entrants?

The case studies provided some support for each EM proposition, but outcomes were mixed overall. The tenet that environmental and economic measures are compatible enjoys support when examined over the long-term. Indeed, the longer the time perspective, the more early research and development costs are relativized. Contrary to claims that catalytic convertors and CAFE standards would destroy the US auto industry, TF allowed an improvement in air quality and energy efficiency, but also served to reinforce the ICE and the manufacturers whose market dominance depended on it. Further, the proposition that "pollution prevention pays" is necessarily correct whenever genuine attempts are made to internalize externalities, for example through carbon markets. Thus the EU ETS is leading to GHG reductions, albeit at a modest pace to date. Also, pro rata subsidies for electricity generation from renewables have pushed conversion technologies up the learning curve, and resulted in some substitution of generation from polluting fossil fuels. The response to the question of whether accelerated technological innovation led to improved environmental performance is broadly affirmative.

Little evidence was found, however, of ecomodernist practices leading to sectoral structural change. The promotion of RES-E is the best example to date of how policy measures can promote the gradual emergence of low-carbon technologies and new industries, at relatively low cost to consumers. However, it is an exceptional case. Both the US TF and EU ETS case-studies revealed how incumbents soak up regulatory pressures and avert sectoral structural change. Hence the response to the second research question is that technological forcing led mostly to incremental improvements to standard processes and products, with few signs of sectoral structural change. The key explanation is incumbent behavior. The prediction that modernization losers would offer resistance to change proved correct. Each case-study found coordinated and persistent strategies by incumbents to derail, dilute or defer ecological modernization processes. Vested interests sought to preserve their industrial and market status primarily by developing political skills to resist regulation, and resorted to technological renewal as a second best option. Thus the case-studies revealed that the resistance of modernization losers is indeed a significant boundary condition, since their actions side-track the empirical practice of EM towards preservation of "business as usual," serving to postpone—or even undermine—implementation of the EM principle of achieving compatibility between economic and environmental objectives. In summary, the capacity of technological forcing to translate ecological modernization theory into effective policy and practice has proved limited.

These findings help clarify the challenges for future climate policy. Instruments such as TF, ETS and FITs demonstrate the value of the regulatory drive towards technological innovation, bringing economic and ecological modernization in its wake. Public administration expertise went into iterative improvements of the technical dimensions of policy design. This allowed important progress. However, less attention was devoted to major obstacles, particularly the role of vested interests. Incumbents proved creative in developing resistance strategies. An initial—or "fire fighting"—tactic was the attempt to derail policy by legal challenges. Where this failed, a fall-back position was to attain minimal compliance, but only after extracting postponements. A long-term strategy to favor their financial interests was to influence policy formulation upstream, by downscaling requirements or re-categorizing products and processes to escape regulation altogether. An accompanying strategy was to publicize exaggerated costs, whilst avoiding mention of benefits accruing to them.

A key lesson is that technology-based policies need to be accompanied by economic and political strategies to counter-act the unwillingness of incumbents to cooperate. Technological acceleration does not happen simply through "natural selection" at the level of firms and their technology choices, but requires focused and coordinated political responses to shape the business environment. In the past, this was typically done by threatening to use sticks (e.g. fines). But this is too partial and downstream a response. Powerful modernization losers rarely face fines because they massage the policy framework upstream to avoid coming into non-compliance. The use of carrots in the form of market incentives represents progress, but it too can be subverted if incumbents allocate themselves excessive returns. The challenge for policy makers is to develop greater institutional capacity to counter these trends. Doing so requires the reinforcement of their basis of legitimatization by recourse to public opinion and civil society movements. They can also nurture a critical mass of actors, especially new market entrants, who are supportive of technological forcing policies because they benefit from them. The history of feed-in tariffs demonstrates that this can be done.

Thus the question of whether policy instruments providing incentives to embrace innovation should be directed mainly towards incumbents or new entrants receives a qualified response. In all cases, policy must encourage new entrants. However, incumbents must also be pushed out of their rut. Here it is important to build on the recognition that the economic interests of subcategories of incumbents often diverge. Policy makers can split the incumbents' camp by playing on relative competitive advantage. The US authorities had the opportunity to reinforce CAFE standards by actively enlisting the support of those car producers who could easily exceed the minimum standards—but did not do so. Major failings of the EU ETS were the allocation of permits gratis and the decision to bring electricity generation into the same scheme as industries exposed to international competition. A separate scheme for protected sectors would have made it easier to (a) impose permit auctions from phase one, and (b) extend auctioning and create a unified scheme in later phases. In practice, the EU ETS did the opposite: with the implausible ambition of designing a global scheme, it went from a unified to a multi-tier system and diluted environmental gains in the process. The history of policy support to RES-E, particularly in Germany and Denmark, shows that FITs do encourage new conversion technology purveyors and new entrants into generation markets. On the other hand, tradable certificate schemes, such as the UK Renewables Obligation, largely favor incumbents.

Future policy rounds need to understand these past errors and find political will to avoid them. The situation is urgent. Achieving 75–80 percent GHG cuts by 2050 is a major climate challenge, and there is no prospect currently of meeting those targets without structural change in the major emitting industries. A major change process needs to be initiated in the 2010s, so that it can gather momentum in the 2020s. Whilst we do not and may never have a blueprint to guide the process, the ecological modernization of the fossil fuel economy requires that the redefinition of entire sectors be systematically promoted, year on year, decade by decade.

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